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Predicting Tropical Cyclone Genesis

PI: Melinda S. Peng
Naval Research Laboratory
Monterey CA 93943-5502
Phone: (831) 656-4704 fax: (831) 656-4769 e-mail: melinda.peng@nrlmry.navy.mil

Co-PI: James Hansen
Naval Research Laboratory
Monterey CA 93943-5502
Phone: (831) 656-4741 fax: (831) 656-4769 e-mail: james.hansen@nrlmry.navy.mil

Co-PI: Tim Li
IPRC/SOEST, University of Hawaii at Manoa
1680 East-West Road, POST Building 409B
Honolulu, Hawaii 96822
Phone: (808) 956-9427 fax: (808) 956-9425 e-mail: timli@hawaii.edu

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LONG-TERM GOALS

The long-term goal of this project is to provide probabilistic genesis forecast guidance to operational forecasters and develop a genesis index to provide guidance for operational dynamical model prediction of tropical cyclone (TC) genesis. Once regions of high TC genesis probability are identified, a movable, multi-nested version of the COAMPS with resolution of roughly 3 km or less in the inner most grid will be utilized for predicting the genesis event.

OBJECTIVES

The objective of this project is to develop a statistical TC genesis model that is capable of separating developing and non-developing tropical disturbances. A TC genesis index will be constructed to provide the probability of cyclogenesis, based on NOGAPS global analysis and forecast fields.

APPROACH

Our approach is to identify distinctive characteristics associated with developing and non-developing disturbances in the tropical western North Pacific and Atlantic oceans. A box-difference index (BDI) is introduced to quantitatively determine the relative importance of dynamic and thermodynamic parameters in determining the genesis events. Once key genesis parameters in different basins are determined, then we can obtain several nonlinear logistic regression models with different combination of these predictors. We finally apply BIC (Bayesian Information Criterion) on these models to optimally determine the best model for TC genesis probability forecast at different basins.

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WORK COMPLETED

In the past year, we primarily worked on (1) further refining genesis predictors, (2) applying BIC on nonlinear regression model to optimally determine the best prediction model (3) evaluating the model performance by conducting hindcast TC genesis forecasts in the WNP from year 2009 to year 2011(until September 20) and (4) operational test run for JTWC (Joint Typhoon Warning Center).

It is well known that selection of predictors is one of the key factors for performance of a statistical prediction model. Previously, we intentionally decreased the number of predictors to overcome the overfitting problem. A BDI methodology (which takes into account of both the mean and spreading of samples within the developing and non-developing groups) was applied to objectively and optimally determine the best predictors for the regression model. However, by doing this, we can only know a few important predictors, we still don't know how many should we include in the model.

We have reported the performance of refined model with hindcast of year 2009 summer TCs in the WNP in previous report. The hindcast of WNP TC genesis during 2009-2011 summers with the refined genesis forecast model shows similar result with that. The hit rate is around 68% with false alarm rate of 20%. But since this is three-year hindcast validation, the performance of our model based on the validation should be robust.

RESULTS

From the latest results of Fu et al. (2011) paper, the table listing the most important parameters for TC genesis in the WNP is obtained (Table 1). This table is different from previous one in that the single level divergence and zonal wind shear are replaced with vertically averaged ones. By using of the vertically averaged value of these parameters as predictors, our model is expected to be more stable. Then we re-constructed our model based on the new list. The results show that the hit rate is generally improved, but it is also accompanied by a little increase of false alarm rate (Fig. 1).

Table 1 BDI of key genesis parameters in the western North Pacific

Variable name	BDI	
	sign	magnitude
800 hPa maximum relative vorticity	+	0.46
Rain rate (20^o x 20^o)	+	0.42
1000-400 hPa vertically averaged $\partial u / \partial y$ (20^o x 10^o)	–	0.39
1000-500 hPa vertically averaged divergence (10^o x 10^o)	–	0.38
925-400 hPa water vapor content (10^o x 10^o)	+	0.24
SST (20^o x 20^o)	+	0.13
Translational speed	–	0.06

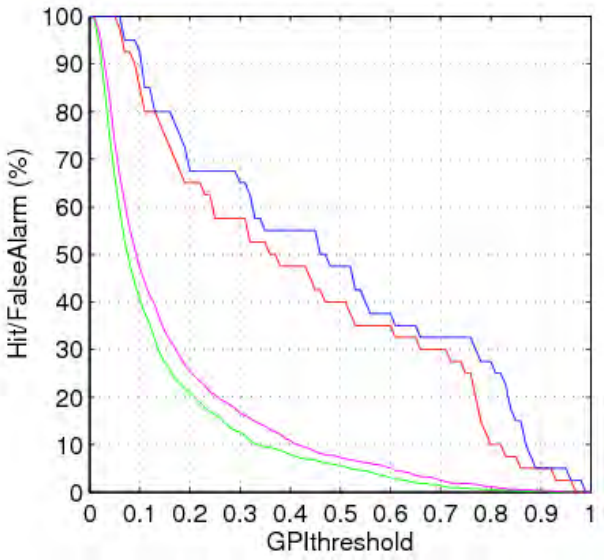

Fig. 1 2009-2011 summer WNP TC genesis hindcast from a 5-predictor model (800 hPa maximum vorticity, rain rate, 925-400 hPa water vapor content, 750 hPa du/dy and 1000 hPa divergence, blue/pink curve represents hit rate/false alarm rate) and another 5-predictor model (blue/pink curve represents hit rate/false alarm rate) same with previous one except that du/dy and divergence are replaced with vertically averaged values.

Given those key parameters, we were also trying to determine a best model which has higher hit rate while its false alarm rate is lower. Despite that it primarily depends on our needs during the operational forecasts, an optimal model is still needed. We use BIC (Bayesian Information Criterion) to optimally determine the best model. It consists of twice the negative of the log likelihood plus a penalty for the number of parameters fit, and the preferred regression will be the one with the smallest BIC. The following is the definition of BIC:

$$BIC = -2\ln[\Lambda(b)] + (K+1)\ln(n)$$

with

$$\Lambda(b) = \prod_{i=1}^{n} \frac{y_i \exp(b_0 + b_1 x_1 + \ldots + b_k x_k) + (1 - y_i)}{1 + \exp(b_0 + b_1 x_1 + \ldots + b_k x_k)}$$

is joint likelihood, K is the number of predictors, n is the number of sets of observations. yi is 1 for genesis and is 0 for nongenesis.

According to BIC, a model with three predictors including 800 hPa maximum vorticity, rain rate and vertically averaged du/dy) is the best model. Figure 2 shows the comparison of this model with a 5-predictors model for hindcast of 2009-2011. It can be seen that the false alarm rate is generally decreased with also decreased hit rate. If we focus on the threshold of 0.2-0.3 which is the one we used

to set, we can find hit rate decreased not as much as false alarm rate. If we set threshold as 0.2, the hit rate is about 68% for both 5-predictor model and 3-predictor model, while the false alarm rate decreases from 25% to 20%. It suggests BIC is efficient in helping determine the optimal model.

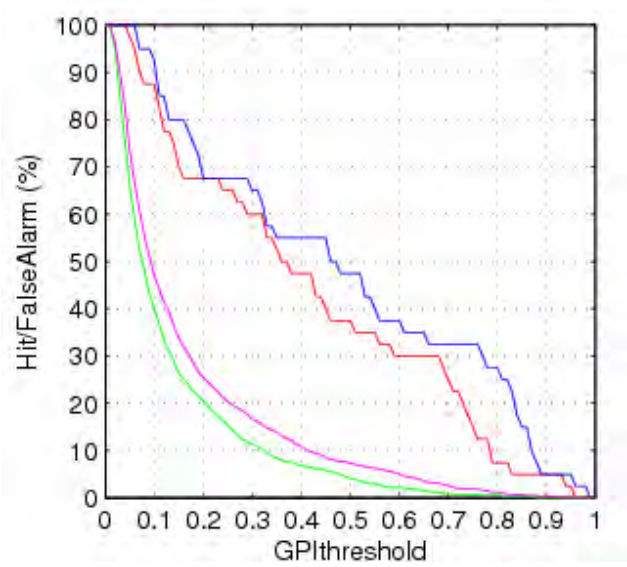

Fig. 2 2009-2011 summer WNP TC genesis hindcast from a 5-predictor model (800 hPa maximum vorticity, rain rate, 925-400 hPa water vapor content, 750 hPa du/dy and 1000 hPa divergence, blue/pink curve represents hit rate/false alarm rate) and a 3-predictor model (800 hPa maximum vorticity, rain rate and vertically averaged du/dy, red/green curve represents hit rate/false alarm rate)

JTWC forecasters are very interested in our forecasts. From 2011 summer, we began to collaborate with JTWC on TC genesis forecast. Due to the operational needs for TC genesis forecasts products from JTWC, while the required satellite data for our latest model can not be obtained in real time, we currently only provide JTWC TC genesis forecasts products from a model without satellite data input. We created a website to post our forecast products. JTWC forecasters will evaluate our forecasts and send feedbacks to us. In their recent report to us, they suggest the trend of GPI (Genesis Potential Index) is beneficial for JTWC forecasters (Fig. 3,4).

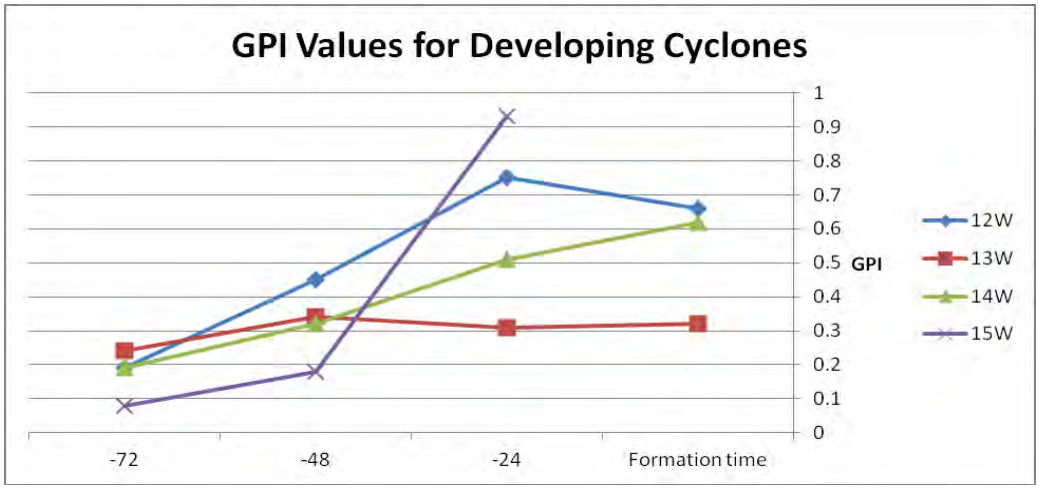

Fig. 3: GPI values preceding JTWC classification of each cyclone as a tropical depression.

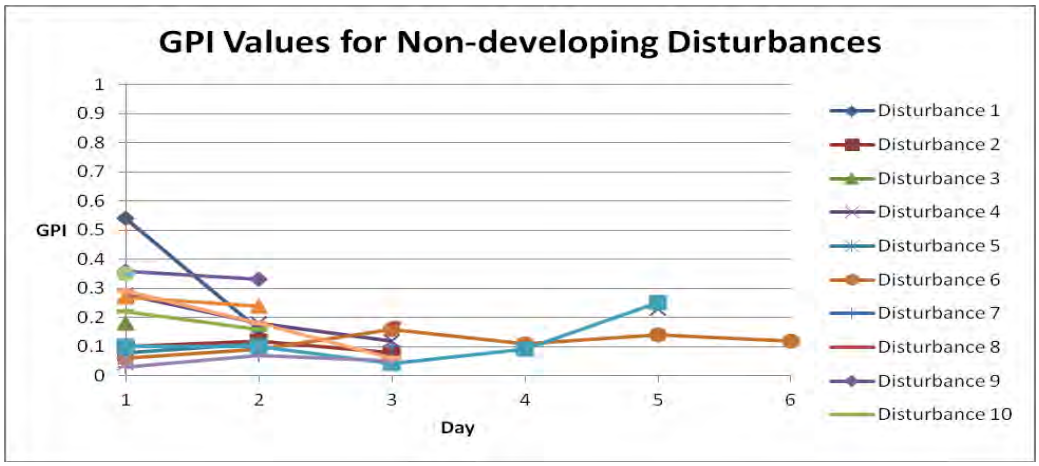

Fig. 4: Same as Fig. 3 except for non-developing disturbances.

They found that developing systems tended to show either a distinct increasing trend in GPI, particularly between 48 and 24 hours prior to formation, or a steady trend over several days at values exceeding the 0.2 development threshold (Fig 3). Non-developing systems tended to maintain GPI values below 0.2 and, in the cases in which values exceeded 0.2, GPI tended to decrease over time (Fig. 4). Their findings suggest GPI is a great utility for forecasters.

IMPACT/APPLICATIONS

The successful completion of this project may provide an operational TC genesis probability forecast system based on the NOGAPS global analysis and forecast fields. Operational TC forecast centers may use this product as a reference for issuing a TC formation alert/warning at a lead of 24-72 hours. This

product can also provide guidance about where to place a high-resolution regional model (such as COAMPS) for dynamic TC genesis prediction.

TRANSITIONS

The forecast models developed by this project may readily transition to a 6.4 project for quasi-operational tests.

RELATED PROJECTS

This project is closely related to the NRL 6.2 funding on "Predicting tropical cyclone genesis using NOGAPS". Knowledge gained from this project will help to improve the prediction of tropical cyclone genesis.

PUBLICATIONS

Peng, M. S., B. Fu, T. Li, and D. E. Stevens, 2011: Developing versus non-developing disturbances for tropical cyclone formation. Part I: North Atlantic. *Monthly Weather Review, accepted.*

Fu, B., M. S. Peng, T. Li, and D. E. Stevens, 2011: Developing versus non-developing disturbances for tropical cyclone formation. Part II: Western North Pacific. *Monthly Weather Review, accepted.*